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INFLUENCE OF TEMPERATURE ON THE HOURLY DISTRIBUTION OF THE NOCTURNAL FLIGHT OF ARCTIINI (LEPIDOPTERA, EREBIDAE, ARCTIINAE) IN AN AREA OF THE TAPAJÓS NATIONAL FOREST, EASTERN AMAZON

ABSTRACT: The nocturnal flight patterns of Arctiini moths from Tapajós National Forest, Belterra, Pará, Brazil, are analyzed in this paper. The moths were captured each month from May 2019 to February 2020 on three consecutive nights during the waning/new moon phase, using the Pennsylvania model light trap. Species composition was evaluated. Richness and abundance were used in a circular analysis and correlated with temperature. A total of 412 individuals belonging to 94 species were collected, distributed among all seven tribes of Arctiini. Most species (S= 72 or 76.6%) occurred in one and two sampling scheduled times. The peaks for richness (S= 27) and abundance (N= 101) were recorded in the first (8 p.m.) and last (5 a.m.) scheduled sampling times, respectively. These findings were corroborated by the circular analysis. Our results indicate that sampling should be conducted throughout the night to obtain an accurate representation of the Arctiini fauna in a given area. The correlation obtained shows that the richness was influenced by the temperature.

KEYWORDS: Light trap, Dense Ombrophilous Forest, Tiger-moths, Flight.

INFLUÊNCIA DA TEMPERATURA NA DISTRIBUIÇÃO HORÁRIA DE VOO NOTURNO DE ARCTIINI (LEPIDOPTERA, EREBIDAE, ARCTIINAE) EM UMA ÁREA DA FLORESTA NACIONAL DO TAPAJÓS, AMAZÔNIA ORIENTAL

RESUMO: Este estudo analisou o horário de atividade de voo de Arctiini em uma área da Floresta Nacional do Tapajós, Belterra, Pará. As mariposas foram mensalmente capturadas no período de maio de 2019 a fevereiro de 2020, durante três noites consecutivas, na fase de lua minguante/nova, utilizando armadilha luminosa modelo Pensilvânia. Avaliou-se a composição de espécies, a riqueza e a abundância foram utilizadas para realizar a análise circular e relacioná-las com a temperatura através da correlação. Foram capturados 412 indivíduos pertencentes a 94 espécies distribuídas em todas as sete tribos de Arctiini. A maior parte das espécies (S= 72 ou 76,6%) ocorreram em um e dois horários. Os horários de pico, para a riqueza (S= 27) e abundância (N= 101) foram registrados nas primeiras horas (20h) e nas finais (5h) de coleta, respectivamente, corroborados pela análise circular. Desta forma, recomenda-se que a captura seja realizada ao longo da noite, com a finalidade de representar o máximo possível a composição faunística de Arctiini. A correlação obtida mostra que a riqueza sofreu influência da temperatura.

PALAVRAS-CHAVE: Armadilha luminosa, Floresta Ombrófila Densa, Mariposas-tigre, Voo.

INFLUENCIA DE LA TEMPERATURA EN LA DISTRIBUCIÓN HORARIA DEL VUELO NOCTURNO DE ARCTIINI (LEPIDOPTERA, EREBIDAE, ARCTIINAE) EN UN ÁREA DEL BOSQUE NACIONAL DE TAPAJÓS, AMAZONÍA ORIENTAL

RESUMEN: Este estudio analizó el horario de actividad de vuelo de Arctiini en un área de la Floresta Nacional Tapajós, Belterra, Pará. Las polillas fueron capturadas mensualmente desde mayo de 2019 hasta febrero de 2020, durante tres noches consecutivas, en la fase de luna nueva/menguante, utilizando una trampa de luz modelo Pensilvania. Se evaluó la composición de especies, se utilizó la riqueza y la abundancia para realizar el análisis circular y relacionarlas con la temperatura mediante correlación. Contamos 412 individuos pertenecientes a 94 especies distribuidas en las siete tribus de Arctiini. La mayoría de las especies (S= 72 o 76,6%) se presentaron en uno y dos momentos. Los momentos pico de riqueza (S= 27) y abundancia (N= 101) se registraron en las primeras horas (20 h) y al final (5 h) de recolección, respectivamente, y fueron corroborados por el análisis circular. Por lo tanto, se recomienda que la captura se realice durante la noche, para representar lo más posible la composición faunística de Arctiini. La correlación obtenida muestra que la riqueza fue influenciada por la temperatura.

PALABRAS CLAVES: Trampa de luz, Bosque Ombrófilo Denso, Polillas tigre, Vuelo.

INTRODUCTION

Insects are a dominant group on Earth, partly due to their ability to fly (GRIMALDI; ENGEL, 2005) and to perceive and interpret the environment (GULLAN; CRANSTON, 2017).

Research on this taxon requires major efforts in order to provide input regarding patterns of richness, diversity, and distribution, especially when this knowledge is accompanied by information on the biological and taxonomic aspects of the species (GOMES et al., 2010). However, some environmental factors such as temperature, relative humidity, luminosity, wind, time, radiation, food, and ecological relationships act directly and indirectly on the population fluctuation and distribution of insects, (GALLO et al., 2002). Temperature acts directly, affecting development and behavior, and indirectly, interfering with insect feeding (COSTA et al., 2011).

As a means of gaining quantitative and qualitative knowledge of the fauna, the light trap has been one of the most widely used collection methods in the field of entomology for accessing and monitoring certain groups (BARRETO; PEZZINI, 2015; ZENKER et al., 2020), which are characterized by positive phototropism due to their attraction to light (COELHO et al., 2021).

Lepidopterans, especially moths, are mostly nocturnal, show stimuli when exposed to a light source and are significantly well represented in captures using light traps (DUARTE et al., 2012; RABL et al., 2019; BREHM et al., 2019).

Arctiinae moths can be collected in this type of trap for different study purposes, notably due to their importance as bioindicators in environmental monitoring (HILTY; MERELENDER, 2000).

Arctiini is one of the tribes that together with Amerilini, Lithosiini and Syntomini (ZENKER et al., 2017) make up the Arctiinae subfamily is part of the Erebidae family (ZAHIRI et al., 2012). Of these, only Arctiini and Lithosiini are found in the Neotropical region (HEPPNER, 1991). Arctiini (tiger moths) contains the most species (TRIPLEHORN; JOHNSON, 2011), with 4,761 known from the Neotropical region (HEPPNER, 1991), 1,225 for Brazil (FERRO; DINIZ, 2010) and 1,060 species in the Amazon (VALENTE; TESTON, 2022).

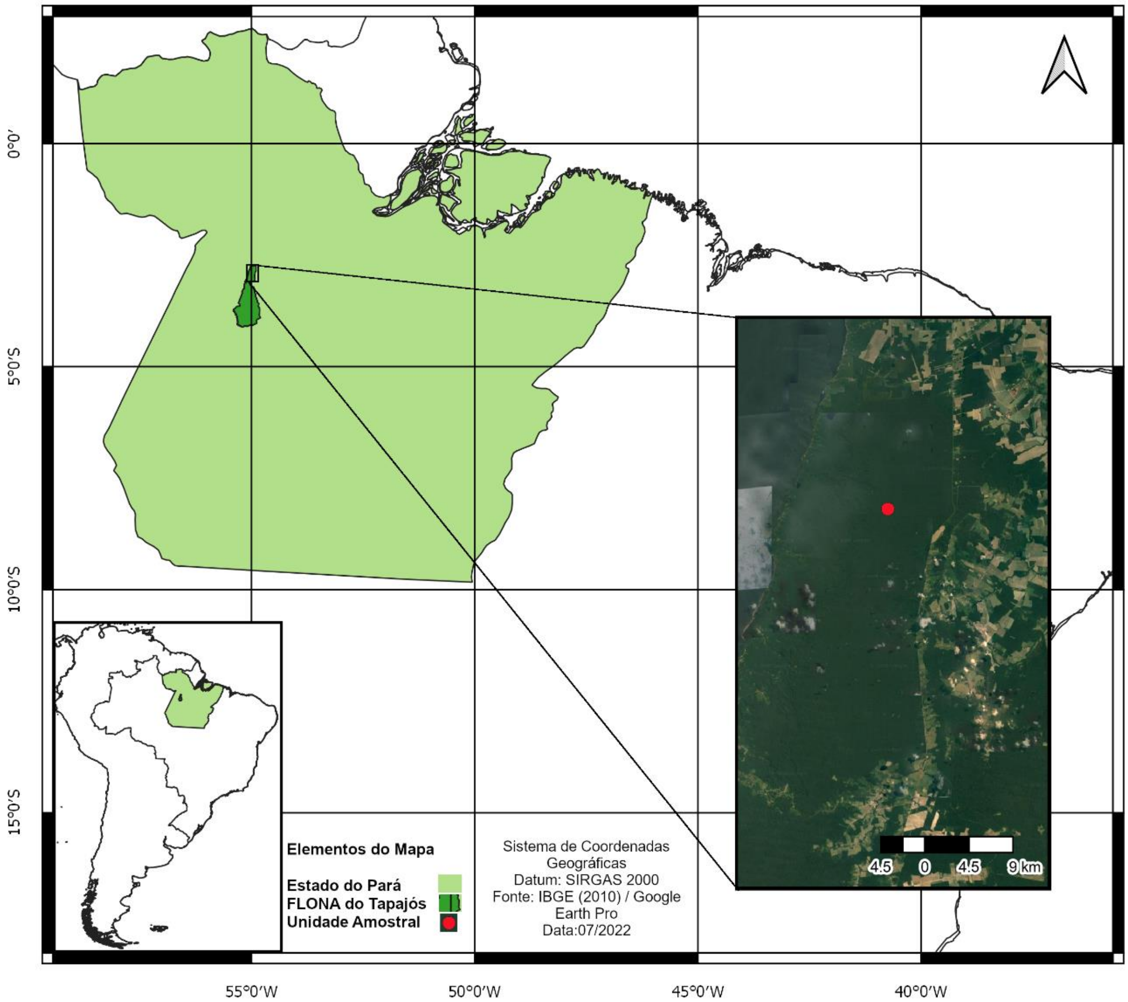
Studies that address the flight activity schedule of lepidopterans are still insufficient (SILVEIRA NETO et al., 1975; LOURIDO et al., 2008; SCHERRER et al., 2013; CAMARGO et al., 2016), especially when jointly involving meteorological parameters such as temperature, which is mentioned as an influencing factor in the flight of lepidopterans (MARINONI et al., 1997; MARINONI et al., 1999; MONTERO-MUNHOZ et al., 2013). Among the research activities that have contributed to the subject in question were those recently carried out in the Emas National Park in the Cerrado (MORENO et al., 2021), Serra do Pardo National Park (TESTON, 2021a) and the Amazon National Park stand out (TESTON, 2021b), both in the Amazon.

With this in mind, the present study aims to: i) analyze the composition, abundance, richness and hourly distribution pattern of nocturnal flight by Arctiini species t in the Tapajós National Forest, Pará; ii) relate abundance and richness with temperature throughout the night.

MATERIAL AND METHODS

The study was carried out in an area of the Tapajós National Forest (TNF), in the municipality of Belterra, Pará. The TNF is characterized by a predominant vegetation cover of Dense Ombrophilous Forest, composed of large trees, woody lianas, palm trees and epiphytes (CORDEIRO, 2005). Inside the TNF, the Large-Scale Biosphere-Atmosphere Program in the Amazon (LBA) has a 45 m high platform tower (geographical coordinates 02º51'23.3"S and 54º57'31.0"W) (Figure 1) which was used as a sampling unit (SU), located at km 67 on the BR - 163 federal highway (Santarém-Cuiabá) (ICMBio, 2019) and close to the forest management logging area (BEZERRA et al. , 2018).

Figure 1. Location of the collecting unit (red circle) in Tapajós National Forest, Pará, Eastern Amazon. Satellite Google Earth image



Source: Prepared by the authors.

The thirty sampling nights were carried out over a period from May 2019 to February 2020, during the waning and/or new moon period, on three consecutive nights. The moths were captured with a Pennsylvania model light trap (FROST, 1957), equipped with an ultraviolet fluorescent lamp F15 T12 LN and a collector container containing fixative (96º GL alcohol), turned on at dusk (7 p.m.) and turned off at dawn (7 a.m.) (VALENTE et al., 2018). The trap was installed on the platform tower at a height of 2 m, and the insects were collected according to the time of capture at intervals of every hour and later stored in plastic pots.

The collected samples were transported to the Laboratório de Estudos de Lepidópteros Neotropicais (LELN) of the Universidade Federal do Oeste do Pará (UFOPA), where the moths were screened and quantified. At least one or two specimens per species were pinned and dried in a laboratory oven at 40°C for two days. The remaining specimens were stored in entomological envelopes. The vouchers were deposited in the LELN collection attached to the Museu de Zoologia (MZSTM) of the Programa de Ciências Naturais UFOPA.

The moth fauna was analyzed using the following metrics: composition, abundance (N) and richness (S).

Circular analysis was used to evaluate the hourly flight distribution of Arctiini considering their abundances and the species richness captured hourly by applying the Rayleigh test (ZAR, 2010) using ORIANA 4.20 software (KOVACH, 2013).

Species richness and abundance were correlated with nightly averages of the meteorological variable air temperature (ºC), using Pearson's correlation using the PAST software (HAMMER et al., 2001). Air temperature was obtained from the LBA Program Meteorological Station.

RESULTS AND DISCUSSION

A total of 94 species (S) and 412 individuals (N) were collected representing all seven subtribes of Arctiini: Arctiina, Callimorphina, Ctenuchina, Euchromiina, Pericopina, Phaegopterina and Spilosomina (Table 1). Two species are new records for the Brazilian Amazon: *Trichromia phaeocrota* (Dognin, 1911) and *Oodoptera guianensis* Laguerre, 2019 (Table 1), with the second being the first time cataloged for Brazil. The species *Virbia epione* Druce, 1911 (N= 68), *Virbia subapicalis* (Walker, 1854) (N= 31) and *Virbia* sp. 1 (N= 23) were the most abundant and belonging to Arctiina (Table 1).

The species richness (S= 94) collected in TNF represents 8.9% of the 1,060 species listed for the Amazon (VALENTE; TESTON, 2022) and 42.5% of the 221 species previously reported for this conservation unit (FREITAS , 2014), considering that the two new records belong to Phaegopterina, which is the dominant subtribe in terms of species diversity in studies carried out in the Brazilian Amazon with light traps (TESTON et al., 2012; TESTON; CORREA, 2015; TESTON et al. ., 2020). Arctiina represented by the genus *Virbia* was quite significant in species abundance. According to Brehm (2006) this predominance can be attributed to the mouthparts since the species of this genus have a short proboscis (JACOBSON; WELLER, 2002), which only allow the absorption of surface fluids, and this may be an adaptation to life in the potentially nectar-poor understory (BREHM, 2006).

Table 1. Number of Arctiini collected at night (7 p.m. to 6 a.m.), with light traps, Tapajós National Forest, Eastern Amazon, between May, 2019 and Feb, 2020. New record for Amazon (*) and Brazil (**).

Subtribe/Species	Hours												
	7	8	9	10	11	12	1	2	3	4	5	6	Total
Arctiina													
Virbia epione Druce, 1911									1	15	47	5	68
Virbia medarda (Stoll, [1781])										1	4	1	6
Virbia subapicalis (Walker, 1854)	4	2		1					2	12	9	1	31
Virbia sp.1										1	18	4	23
Virbia sp.2	1	1		1	1								4
Callimorphina													
Utetheisa ornatrix (Linnaeus, 1758)		1						1					2
Ctenuchina													
Aclytia gynamorpha Hampson, 1898										1			1
Aclytia heber (Cramer, 1780)		1											1
Correbidia calopteridia (Butler, 1878)	1	7	1	1					1				11
Correbidia sp.1	1	1	1	1				1					5
Correbidia sp.2		1											1
Delphyre dizona (Druce, 1898)	1		1					1					3
Delphyre flaviceps (Druce, 1905)		1	1	1		1							4
Ecdemus carmania (Druce, 1883)		1											1
Ecdemus obscuratus Schaus, 1911		1											1
Episcepsis luctuosa (Möschler, 1877)	1												1
Eucereon aoris Möschler, 1877		1											1
Eucereon obscura (Möschler, 1872)	1	1											2
Heliura perexcavatum (Rothschild, 1912)							1						1
Heliura tetragramma (Walker, 1854)	1												1
Hyaleucerea erythrotela (Walker, 1854)	1		1										2
Ptychotricos zeus Schaus, 1894	1				1								2
Theages sp.		1	1										2
Tipulodes rubriceps Dognin, 1912		1											1
Uranophora walkeri (Druce, 1889)				1									1
Euchromiina													
Autochloris proterva (Draudt, 1916)									1				1
Calonotos aequimaculatus Zerny, 1931		1											1
Calonotos aterrima tripunctata Druce, 1898					1								1
Cosmosoma metallescens (Ménétriés, 1857)								1					1
Hypocharis albicincta Cerda, 2008			1							1			2
Leucotmemis torrida (Walker, 1854)											2		2

Leucotmemis varipes (Walker, 1854)		2	9	2	4	1			1				19
Macrocneme adonis Druce, 1884											1		1
Phoenicoprocta vacillans (Walker, 1856)	1	1											2
Sarosa acutior (R. Felder, 1869)				1	3								4
Pericopina													
Calodesma albiapex Hering, 1925											2		2
Calodesma collaris (Drury, 1782)											1		1
Hyalurga lauronoides Hering, 1925											1		1
Phaegopterina													
Amaxia erythrophleps Hampson, 1901			1										1
Amaxia lepida (Schaus, 1912)	1			1									2
Amaxia sp.1										1			1
Ammalo helops (Cramer, [1776])											3		3
Baritius eleutheroides Rothschild, 1909	1												1
Carathis sp.	1												1
Cratoplastis barrosi (Almeida, [1968])			4	1									5
Cratoplastis diluta Felder & Rogenhofer, 1874					1								1
Evius albicoxae (Schaus, 1905)											1		1
Glaucostola flavida Schaus, 1905					1	1				2			4
Haemanota holophaea (Hampson, 1905)	1								1				2
Halysidota underwoodi (Rothschild, 1909)								1					1
Himerarctia griseipennis (Rothschild, 1909)			1										1
Himerarctia laeta Watson, 1975		1											1
Hyperandra novata (Dognin, 1924)	2	2											4
Hypidalia sanguirena Schaus, 1905										1			1
Hyponerita lavinia (Druce, 1890)							1						1
Hyponerita persimilis Rothschild, 1909			1										1
Idalus aleteria (Schaus, 1905)										1			1
Idalus vitrea (Cramer, [1780])									1				1
Ischnognatha semiopalina Felder & Rogenhofer, 1874										1			1
Lepidokirbyia venigera Toulgoët, [1983]			1						1				2
Leucanopsis sp.			1										1
Lophocampa citrina (Sepp, [1852])		1	1	1		2	2	1		4	1		13
Lophocampa modesta Kirby, (1892)					1								1
Melese incertus (Walker, 1855)							2	6	1	1	1		11
Melese ocellata Hampson, 1901				1		1		3	16	2			23
Neonerita dorsipuncta Hampson, 1901		1	1	1	4								7
Nezula grisea Schaus, 1896	1	1	2	1					2				7
Nyearctia leucoptera (Hampson, 1920)			1							3	1		5
Oodoptera guianensis Laguerre, 2019 **										1			1
Euplesia sphingidea (Perty, [1833])										1	1		2
Pareuchaetes aurata (Butler, 1875)			1						1				2
Phaeomolis acailandia Laguerre, 2019				1		1							2
Phaeomolis polystria (Schaus, 1905)	1		1	2	7	2							13
Pryteria alboatra alboatra (Rothschild, 1909)												1	1
Pseudepimolis flavonotata (Rothschild, 1909)					1								1

Pseudepimolis incarnata (Hampson, 1901)	1	1	2	2	1				1				8
Psychophasma erosa (Herrich-Schäffer, [1858])									1				1
Regobarrosia flavescens (Walker, 1856)										1			1
Rhipha strigosa (Walker, 1854)	1												1
Scaptius asteroides (Schaus, 1905)											1		1
Symphlebia sp.										1	1		2
Trichromia aurantiipennis (Rothschild, 1909)				1									1
Trichromia declivis (Schaus, 1905)		2											2
Trichromia gaudialis (Schaus, 1905)			2		2								4
Trichromia leucoplaga (Hampson, 1905)			1	4	3	1							9
Trichromia onytes (Cramer, [1777])		1	6	3		1							11
Trichromia phaeocrota (Dognin, 1911) *			1				1						2
Trichromia rosacea occidentalis (Rothschild, 1909)			3										3
Trichromia sorex sorex (Druce, 1902)										6	6		12
Trichromia sp. 1		3						1					4
Trichromia sp. 2		2	3				1						6
Trichromia sp. 3	1												1
Viviennea moma (Schaus, 1905)							1						1
Spilosomina													
Paracles laboulbeni (Bar, 1873)									1				1
Total abundance (N)	25	40	50	28	31	11	9	16	32	57	101	12	412
Total richness (S)	21	27	27	20	14	9	7	9	15	20	18	5	94

Source: Prepared by the authors

In terms of the hourly distribution, it was found that most species (S= 72; 76.6%) occurred exclusively at one and two times, and 10 species (10.6%) were observed with their greatest frequency equal to five times (Table 1). Two species were active for seven to eight hours during the night.

The highest abundances were observed at the end of the night (4 a.m.) and at the beginning of the twilight period (5 a.m.) as evidenced by the circular analysis (r= 0.25; Z= 25.673; p < 0.001). More individuals were recorded at 4 a.m. and 5 a.m. (Tables 1 and 2), respectively (N=57 and N=101) corresponding to 38.3% of the specimens collected, with emphasis on V. epione (N= 62). Richness was accentuated in the early hours of the night (r = 0.201; Z = 7.739; p < 0.001). The times of 8 p.m. and 9 p.m. were the ones that obtained the peaks of species flight activities (S= 27), representing 57.4% of the sampled species (Tables 1 and 2).

The hourly distribution for the peaks obtained for abundance in the late hours (1 a.m. to 6 a.m.) and richness in the early hours (7 p.m. to midnight) were opposed throughout the collection and differed in part from the studies carried out in the Cerrado by Scherrer et al. (2013) and Moreno et al. (2021) and in the Amazon by Teston (2021a, b) who found a pattern of high hourly activity for both metrics mentioned above in the early hours of the night. However, it should be noted that this is the first study that used the "Pennsylvania" light trap to analyze the hourly activity, and the previously mentioned works used the lighted cloth trap and more powerful lamps (250 W), except for Moreno et al. (2021) who used a fluorescent lamp of similar power to this study, but with a black bulb. This study also differed from the pattern found for other families, such as Hedylidae, which showed the highest abundance and richness between 7 p.m. and 9 p.m. (LOURIDO et al., 2008) and Sphingidae, which showed continuous richness throughout the night and variation in peaks of abundance recorded between the intervals of 7 p.m. to 9 p.m., midnight to 2 a.m., and from 4 a.m. to 5 a.m. (CAMARGO et al., 2016).

The hourly activity at the beginning (7 p.m. to midnight) and end times (1 a.m. to 6 a.m.) was representative in terms of richness and abundance, respectively. However, different behaviors were observed for some species. Delphyre flaviceps (Druce, 1905), Neonerita dorsipuncta Hampson, 1901, Phaeomolis polystria (Schaus, 1905), Trichromia leucoplaga (Hampson, 1905) and Trichromia onytes (Cramer, [1777]) were found within the first six hours. V. epione, Virbia medarda (Stoll, [1781]), Virbia sp.1 and Melese incertus (Walker, 1855) showed flight activity in the last six hours (Table 1). V. subapicalis and Lophocampa citrina (Sepp, [1852]) were recorded at almost all times (Table 1). The species composition varied from the beginning to the end of the collection; this fluctuation was also observed by Scherrer et al. (2013), Moreno et al. (2021) and Teston (2021 a, b). This confirms the importance of regularly maintaining the collection until the end of the period to reach a greater quantity and wide variety of species, instead of considering only one collection period, since in the present study relatively more than half of the species were collected either in the initial or final hours.

Table 2. Average hourly temperature in °C (T), abundance (N) and richness (S) of Arctiini collected at night, from 7 p.m. to 6 a.m., with light traps, Tapajós National Forest, between May, 2019 and Feb, 2020.

Parameter	Hours											
	7 p.m.	8 p.m.	9 p.m.	10 p.m.	11 p.m.	12 p.m.	1 a.m.	2 a.m.	3 a.m.	4 a.m.	5 a.m.	6 a.m.
T	27.1	26.7	26.1	25.4	25.0	24.7	24.4	24.2	24.0	23.8	23.7	23.5
N	25	40	50	28	31	11	9	16	32	57	101	12
S	21	27	27	20	14	9	7	9	15	20	18	5

Source: Prepared by the authors

The average temperature (T) per hour ranged from 23.5 to 27.1 ºC over the 30 sampling nights, with an average of 24.9 ºC and a drop of 3.6 ºC until dawn (Table 2). Thus, the correlation between abundance and temperature was negative and weak (-0.105) and richness and temperature was positive and moderate (0.670). The data therefore indicate that an increase in temperature increases the occurrence of Arctiini, that is, the temperature influences the richness. This fact has been confirmed in studies of Arctiini night flight activity carried out in the Serra do Pardo National Park (TESTON, 2021a), in the Amazon National Park (TESTON, 2021b) and in the Cerrado (MORENO et al., 2021). According to Costa et al. (2011) insects are widely distributed in the most varied temperature conditions and have characteristic temperature ranges suitable for their activity. Oliveira (2005) reports in his work that the behavior of moths differs in relation to temperature, when disturbed at 25°C, smaller moths tended to fly and the larger ones ran; at 20°C, almost all animals ran, including the smallest ones, which indicates a possible thermal limitation to flight. Consequently, construction of a knowledge base focused on the effects of climatic conditions on the composition and incidence of species, seeks to contribute towards the conservation of moth biodiversity (MONTERO-MUNHOZ et al., 2013; MOLINA; DI MARE, 2018).

CONCLUSION

Accordingly, this study aims to increase, together with other works of this nature, the knowledge regarding hourly distribution patterns for nocturnal flight among the of Arctiini, thus making it possible to provide more consistent information about the behavior of this taxon under the influence of meteorological variables in the Neotropical region.

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